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(71) Applicant
Dr Alois Stankiewicz GmbH (FR Germany),
3101 Adelheidsdorf, Federal Republic of Germany

(72) Inventors
Heinemann Gahlau,
Christoph Kittel,
Frank Muller-Lippok

(74) Agent and/or Address for Service
Haseltine Lake & Co.,
Hazlitt House, 28 Southampton Buildings, Chancery Lane,
London WC2A 1AT

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B5N

(54) Improvements in or relating to noise insulation materials

(57) Noise insulation material, in particular for fitting loosely into a motor vehicle, comprises a relatively massive portion including a carpet (1) and optionally a dense layer (2) arranged beneath it and a resilient portion arranged beneath the relatively massive portion. The resilient portion includes layers (3) and (4), for example layers of foamed material, having different air flow resistances.

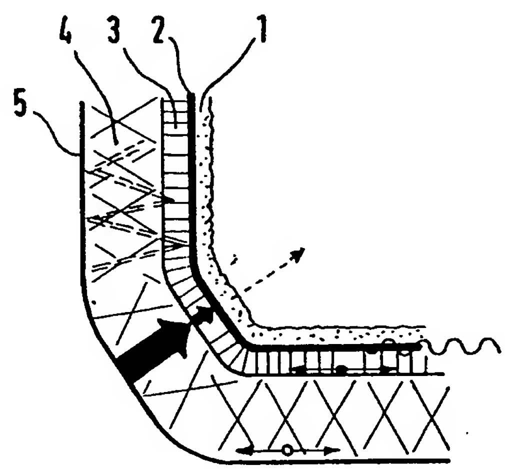

FIG. 1

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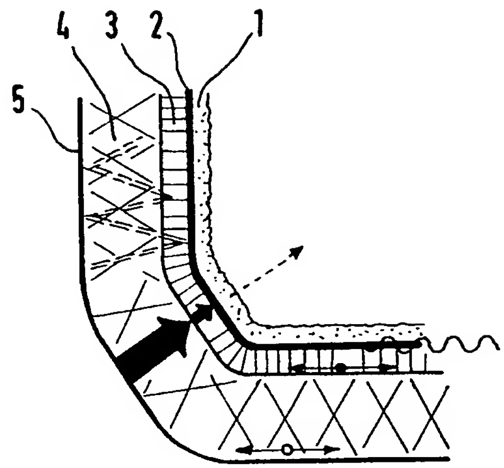

FIG. 1

FIG. 2

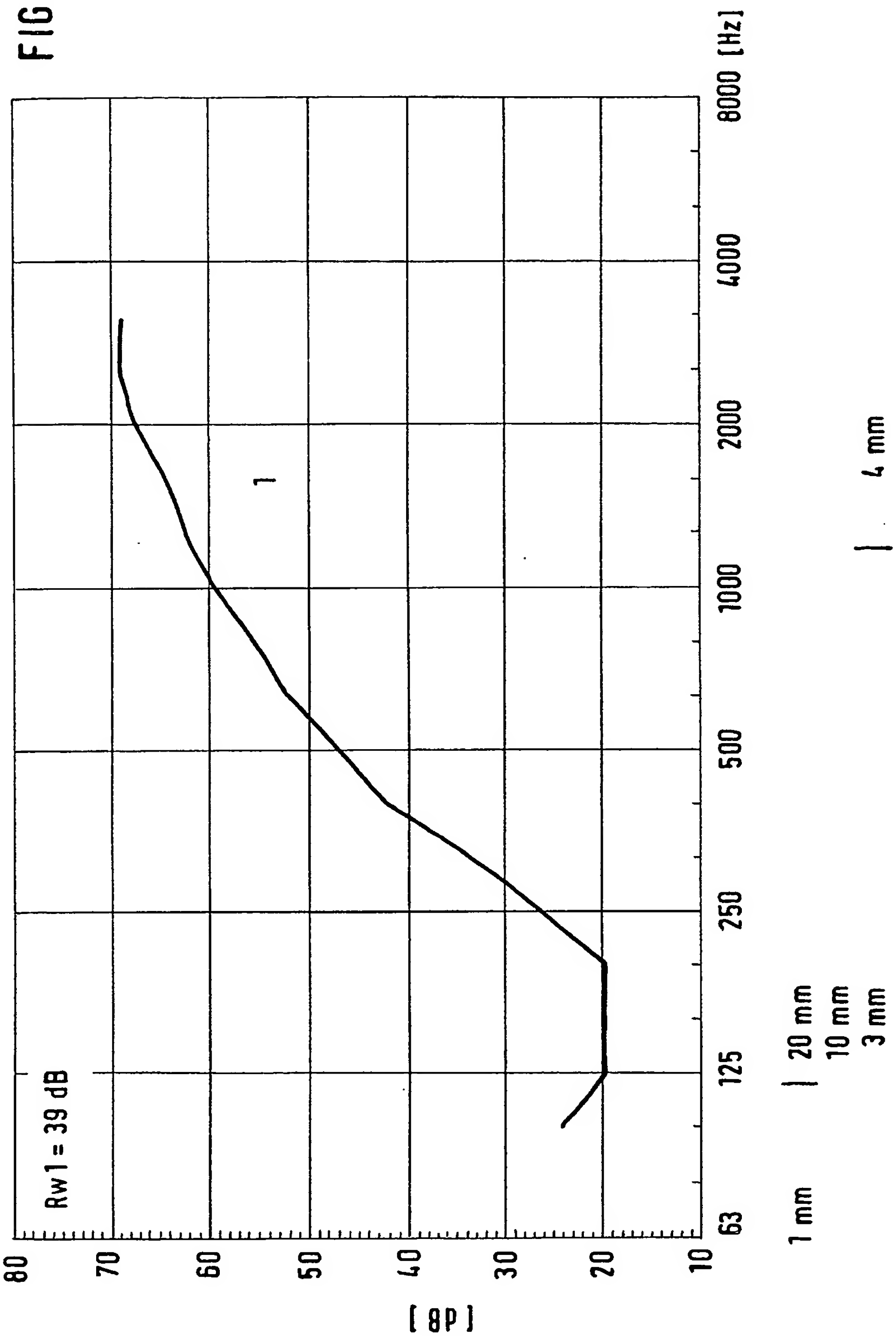
Rw1 = 39 dB
1
80
70
60
50
40
30
20
10
[dB]
63
125
250
500
1000
2000
4000
8000 [Hz]
1 mm
20 mm
10 mm
3 mm
4 mm

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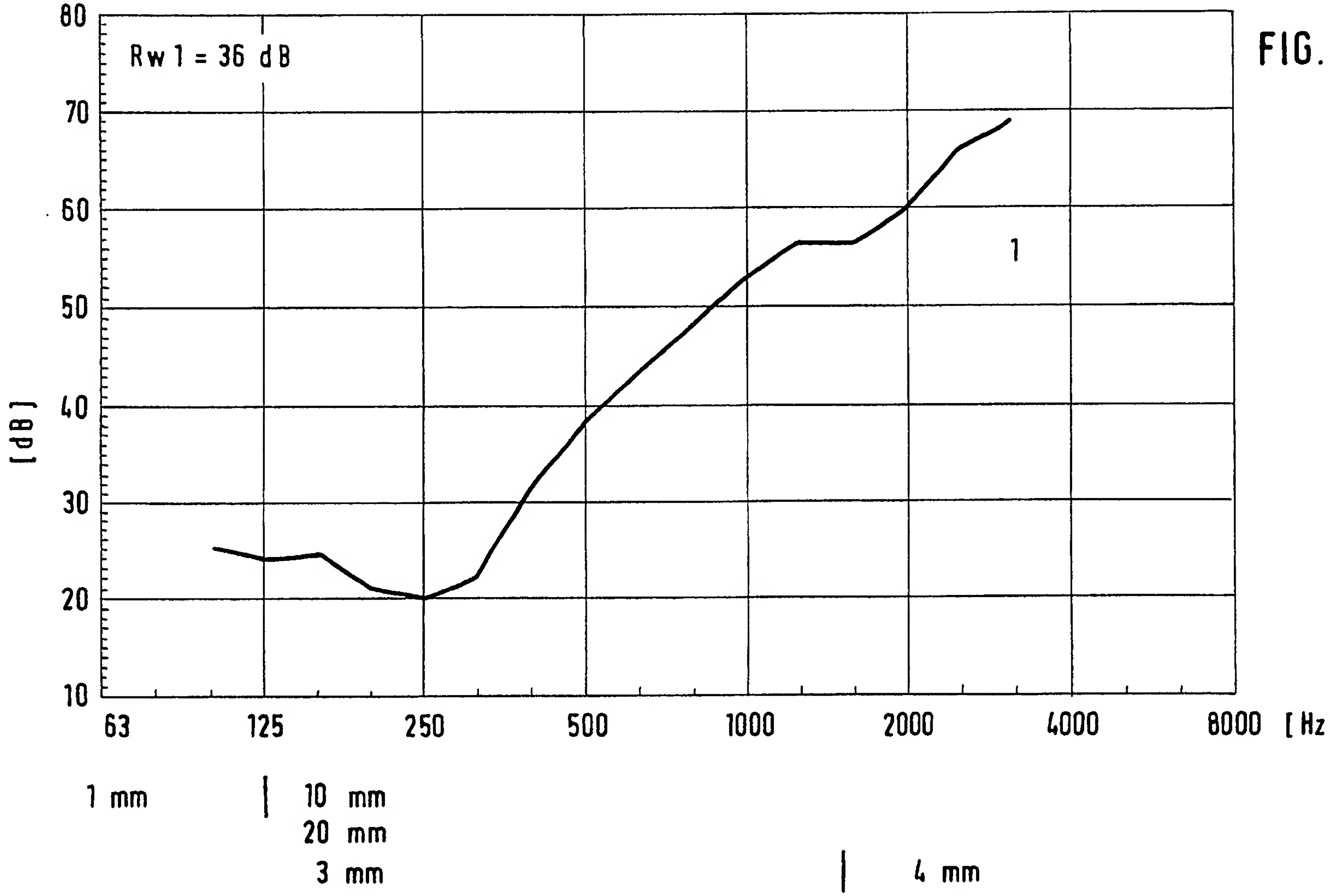
FIG. 3



SPECIFICATION

Improvements in or relating to noise insulation materials

The present invention relates to noise insulation materials and more particularly, but not exclusively, is concerned with such materials which are for inserting loosely into motor vehicles to reduce the interior noise level of the vehicle.

Low interior noise levels in motor vehicles, especially passenger vehicles, are an important selling point having regard to present-day demands for noise comfort. The industry has therefore developed various materials and systems for noise insulation in passenger vehicles, which are now incorporated in production.

Because of the dimensions of the passenger areas and the excitation via the corresponding frequencies from the spectrum of the motor, with 4 cylinder vehicles in particular, disturbing humming noises are caused in the range of the ignition frequency (second motor order), which manifest themselves, during level measurements, as clearly audible resonant vibrations in the passenger area dependent on the speed. It is therefore a general aim of measures taken for noise insulation to avoid resonant vibrations of this type. The rise in level with speed should occur as uniformly as possible.

From the publications (Betzhold, Ch. "The influence of air noise reduction on the interior noise in road vehicles", Glasers Annals, Volume 87, No. 2, February 1963, pages 63 to 66, Georg Siemens Verlagsbuchhandlung, Berlin and Bielefeld; Kurz, K. "Explanation of some typical frequency analyses of vehicle interior noises", ditto, Vol. 87, No. 4, April 1963, pages 207 to 210; VDI 2574 Guideline "Information for the evaluation of the interior noises in motor vehicles"), the connection between engine speeds and resonant vibrations in the passenger area is known. It is also known that the resonance frequency of noise insulation systems, which are constructed as mass-spring systems, should lie outside the disturbing motor frequencies. The thickness of the noise insulation materials used is normally strictly predetermined by the vehicle manufacturer and in this case, and particularly where the insulating layer has a substantially uniform thickness, changed in the resonance frequency can be carried out only to a very limited degree by increasing the mass. A further possibility for the "blurring" of the resonance frequency consists in providing the insulating material with a plastic foam layer of varying thickness, and providing recesses of protuberances in it (cf DE-PS 20 64 445).

With a view to increasing comfort and bearing in mind that construction normally occurs on a conveyor of an assembly production line, decorative equipment, such as floor mats, are also increasingly used to provide noise insulation. This possibility is described in a series of patents and patent applications. Thus the use of carpets with noise- and heat-reducing sub-layers, also in connection with an additional resilient springy material such as foam, is known *per se*. Data on this can be found in DE-OS 30 43 674 "Extrudable mass for the production of a thermoplastic noise- and heat-reducing sub-layer for carpets, and carpets with an extrudable sub-layer of this type, and process for its production". Other similar solutions can be found in DE-OS 31 08 567 "Noise-insulating carpet and process for its production" and in DE-OS 28 09 347 "Process for the production of a deformed noise-insulating floor or wall lining, and the product thus obtained".

In the above three cited publications information is only given about the spatial arrangements of noise reducing systems of this type or about special production processes. The problem of obtaining a shift in resonance frequencies when using constant thicknesses of insulating matieral is not dealt with, nor are solutions to this problem indicated.

In DE-OS 25 38 607 "Noise-insulation material" there is described a three-layered construction comprising carpet/theromoplast/foam, and it is stated that the thermoplast and foam layers can be interchanged, but again there is no information on the shifting of resonance frequencies to remove humming noises. The same is also true for DE-OS 31 04 835 "Back-foamed textile surface lining and a process for its production", which certainly describes a sub-layer which can also be a combination of different foams. However, the special problem of the shift of the resonance frequency out of the range of the engine noises is not discussed. In addition DE-OS 20 06 741 should be mentioned and this substantially anticipates DE-OS 25 38 607 in content and has the title "multi-layer noise-reducing component for an automobile body composed of moulded sheet metal pieces". This publication originates from the specific area of the motor vehicle industry, but containes no indication of a solution to the problem of shifting the disturbing resonance frequencies.

In all of the above-mentioned publications, the acoustic effect of the different arrangements are generally referred to as noise insulation. The expert can find in them no information about possibilities for optimisation with respect to the position or shift of the resonance frequencies with the aim of avoiding disturbing resonance oscillations.

One object of the present invention is to provide a noise insulation system in the form of a decorative mat having a predetermined thickness, irrespective of whether it has a uniform thickness or a non-uniform thickness distributed over its surface, and having an internal structure which can be easily adapted to the special acoustic conditions of the vehicle to which it is to be fitted so that the resonance frequency of the mat lies outside the disturbing motor frequency.

According to the present invention there is provided a noise insulation material comprising

(i) a relatively massive portion comprising a carpet and having first and second opposite surfaces, the first of said surfaces being constituted by a first surface of the carpet, and

(ii) a resilient portion comprising at least two su-

perposed layers having different air flow resistances, the second of said surfaces of the relatively massive portion being superposed on a surface of the resilient portion.

The noise-insulation material of the present invention constitutes a mass-spring system in which the resilient portion serves as the spring of the system. The desired shifts in the resonance frequency of the mass-spring system are obtained by means of the layers having different air flow resistances.

In use of the material of the present invention for noise reduction in vehicles, they are laid loosely and in form-fitting manner on the sheet metal of the vehicle which constitutes one component of the double wal- or mass-spring-system. The resilient (or visco-elastic) portion, which comprises at least two layers, preferably formed of foamed material, having different flow resistances is placed on the sheet metal. On this resilient portion, as a counter mass of the double wall system, there is provided a relatively massive portion preferably including a dense layer that is as resilient as possible, and including a carpet, on its outer side facing the passenger area. The carpet serves as a decoration and also constitutes an outer seal.

The layers of foamed material constituting the resilient portion can thus be arranged according to the position of the resonance frequencies of the passenger interior area. For example, on the vehicle sheet metal there is provided a layer with low flow resistance corresponding to a relatively small air noise absorption during passage of the noise, and on this there is provided a relatively thin layer of foamed material having a high flow resistance, which makes effective noise absorption possible even with a small layer thickness. Such an arrangement forms a low tuned mass-spring system which is preferred for such motor vehicles whose resonance frequencies lie in other ranges.

If the resonance frequencies have an order of magnitude which corresponds, for example, to the resonance frequencies of the system just described, it is desirable to shift the resonance frequencies to higher frequencies without having to change the insulation thickness and the mass-(weight)-relationships. It is a particularly important advantage of the present invention that this is readily possible by regrouping the foamed material layers just mentioned. Thus, the layer of foamed material with the high flow resistance is placed on the sheet metal, and the layer of foamed material with the low flow resistance is placed on the layer having high flow resistance. This in turn is followed by the relatively massive portion comprising the dense layer which may be resilient or rigid and the carpet. By such a regrouping of the two layers of foamed material, surprisingly a shift of the resonance frequency over several thirds can be achieved.

This possibility of producing shifts in resonance frequencies by using the acoustic effects of coupled foam material layers having different flow resistances, in particular in combination with a carpet/dense layer, was not known until now.

The chemical nature of the foamed materials used is *per se* not important for the present invention. All foamed materials can be used which enable the practical production of the insulation materials and which are used for such purposes. Because of their good processability and great variation of width, however, polyurethane-foam materials are particularly suitable.

If desired, some or all of the layers constituting the resilient portion may be formed of non-woven fabric instead of from foamed materials.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made by way of example, to the accompanying drawings, in which:-

Figure 1 is a cross section through one embodiment of vehicle noise insulation material in accordance with the present invention;

Figure 2 is a graph showing the variation in noise-insulation (in dB) as a function of frequency (in Hz) for the material of Figure 1; and

Figure 3 shows the variation in noise-insulation as a function of frequency for the material of Figure 1 after the two foam layers thereof have been regrouped.

Referring to Figure 1 the material constitutes a low tuned mass-spring system in which the layer having low flow resistance is adjacent to the sheet metal of the vehicle i.e. is the lowermost part of the material.

The noise insulation material is in the form of a mat comprising the following layers (seen from the passenger area): a layer of carpet 1, a preferably flexible dense layer 2, a thinner layer of foamed material having high flow resistance 3, and a thicker layer of foamed material having low flow resistance 4. Layers 1 and 2 constitute the relatively massive portion of the material and layers 3 and 4 constitute the resilient portion of the material. A first surface of the relatively massive portion is constituted by a first surface of the carpet 1. The second opposite surface of the carpet is adjacent the first surface of the dense layer 2 and the opposite second surface of the dense layer 2 forms the second surface of the relatively massive portion which is superimposed on the layer 3 of the resilient portion. The mat is laid loosely on the sheet metal 5 of the vehicle. The carpet 1 is used as decoration and forms the outer seal to the passenger area. A mat of this type forms a noise-insulating double wall system in conjunction with the vehicle sheet metal. The distance between the two wall shells of the system is normally determined by the two layers 3 and 4 of foamed material having different flow resistances. Since the mats according to the invention are preferably inserted loosely into the vehicle, friction damping between the foam and the vehicle sheet metal provides a first source of sound insulation. As a consequence of this there is already a reduction in the noise energy conveyed as air noise. Further relative movements occur at the boundary between the layers of foamed material having the low and high flow resistances. The boundary between the layer of foamed material with the high flow resistance and the dense

layer 2 remains almost at rest since the dense layer hardly exhibits any noteworthy bending oscillations. Also energy extraction occurs as a consequence of air noise absorption in the layers of foamed material having low and high air flow resistances. Thus the described combination, enables a low tuned mass-spring system with high noise insulation to be produced by making use of the different energy reducing effects. The resonance frequency of such a construction can be determined in known manner (see e.g. Cremer, L. "Lectures on technical acoustics", Springer-Verlag, Berlin-Heidelberg-New York, 1971). The variation of the noise insulation as a function of the frequency for such construction is shown in Figure 2. In this case, the noise insulation material was placed on sheet metal having a thickness of 1 mm and included (i) a resilient portion comprising a 20 mm thick layer of foamed material having low air flow resistance and a 10 mm thick layer of foamed material having a high air flow resistance and (ii) a relatively massive portion comprising a 3 mm thick layer of dense material and a 4 mm thick layer of carpet.

If for a specific problem the resonance frequency is to be shifted to a higher frequency, without the material thickness and mass-(weight)-relationship being changed, this can be easily done by regrouping the layers of foamed material so that the layer having the high flow resistance is adjacent the sheet metal 5. Then follows the foam layer and the carpet. Thus, in this case, the noise insulation material comprises (i) a relatively massive portion comprising the 4 mm thick layer of carpet and the 3 mm thick dense layer and (ii) a resilient portion comprising a 20 mm thick layer of foamed material having low air flow resistance and a 10 mm thick layer of foamed material having high air flow resistance. This regrouping surprisingly enables a shift in the resonance frequency over several thirds to be achieved as shown in Figure 3.

The dense layer of the relatively massive portion can be flexible in either case. However, in order to provide a firm tread, which is desirable, it may be necessary, in the case of the last described construction, for the dense layer to be rigid. This does not alter the position of the once set resonance frequency, but only influences the damming effect as a function of the frequency in that it reduces the damming effect. Thus the damming effect is influenced by the rigidity or flexibility of the dense layer and this is due to the changed reflection behaviour of the more rigid dense layer compared to the more flexible dense layer.

The effectiveness of the noise-insulating layer directly behind the carpet merely depends on the surface mass and the flexibility. It is known from DE-OS 20 06 741 that the surface mass should be greater than 4.0 kg/m², whilst according to DE-OS 28 09 347 it should be of the order of magnitude of 2.0 kg/². According to the present invention the noise-insulating dense layer should have a minimum surface mass of 2.0 kg/m². The carpet mass is added to the effective surface mass.

A preferred material for the layers having low and high flow resistances are foamed materials, preferably cut foams which may optionally be deformed, although the foamed material may be in the form of moulded parts. However, in an alternative embodiment it is possible to replace the foamed material by non-woven, or similar, textile materials having similar acoustic properties. The carpet may be of any type including those of textile- or plastic fibre construction. By appropriately dimensioning the carpet and selecting its materials of construction having regard to the effective surface mass, the otherwise necessary dense layer per se can be omitted, given the other materials have adequate flexibility in order to achieve the acoustic effect. In this case, the second surface of the relatively massive portion is constituted by the second surface of the carpet.

The present invention is based on the discovery that by using layers, and regrouping the layers, of materials having different low and high flow resistances, it is possible to make resonance-frequency shifts to such an extent that countless insulation problems can be solved in a new way whilst retaining the same thickness of insulation material.

The absolute value of the physical parameters of the individual layers can thus vary within side ranges and the expert is able to adapt these according to the particular problem with which he is involved. As has already been stated, the individual layers can be chemically constructed in any way at all, as long as the principles of the invention are put into effect.

With regard to the use of foamed materials for the layers having different air flow resistances, foamed materials having small pores and relatively high density are suitable for producing layers having high flow resistance. Layers having low flow resistance can be formed from foams which have a larger volume structure and which are lighter.

Closed pore foams are also suitable for layers having a high flow resistance whilst, for layers having low flow resistance, those which are open-pored are suitable. In this case the foams can have the same density, preferably a density of from 25 to 250 kg/m³, in particular 25 to 70 kg/m³. What is essential, according to the invention, is that the layers have different flow resistances.

Generally, for layers having high flow resistance, the flow resistance should be at least 6×10^6 Nsm^{-4}, preferably 6.9×10^6 Nsm^{-4}. On the other hand for layers having low flow resistance the flow resistance should be in the range of 5 to 200 $\times \cdot 10^3$ Nsm^{-4}, preferably from 5 to 30 Nsm^{-4} and in particular about 5.3×10^3 Nsm^{-4}. This means that, as an order of magnitude, the higher flow resistance should be approximately a hundred to a thousand times as large as the lower flow resistance.

The noise insulation material of the present invention can be produced in different ways. On the one hand it is of course possible to join the individual layers of the material together by sticking. Also, of course, only some of the layers of the material may be stuck together, whilst the others are joined together, for example, by one of the ways described below.

Apart from sticking, the noise insulation material

of the present invention can also be produced by other methods of foam production such as back-foaming wherein a semi product is placed in a mould so as to leave a cavity into which foam forming material is introduced to complete the product. Combinations of different techniques can be used.

In the production of the noise insulation materials of the invention by back-foaming in closed moulds, the noise-insulating dense layer below the carpet serves as a barrier which prevents the emergence of foam through the carpet. The layers of foamed material can therefore be produced in known manner by foaming in close moulds using *in situ* foam-forming material and the different layers of foamed material can be produced by changing the ratio of the constituents of the foam-forming material during back-foaming. In an alternative procedure the layers of foamed material can be produced in individual operations by gradual back-foaming and/or sticking or prefabricated moulded foamed parts. It has also proved to be advantageous to use semi-finished products comprising, for example, the carpet, the subsequent dense layer and, optionally, a layer of foamed material having high flow resistance. Such a semi-finished product is then introduced in known manner into a mould and is back-foamed with lighter foam having lower flow resistance. The reversal of this technique is also possible where the semi-finished product, instead of including a layer of foamed material of high flow resistance, has a layer of foamed material of low flow resistance and is back-foamed using foam-forming material which leads to the production of foamed material having high flow resistance.

In an alternative technique a semi-finished product comprising the carpet, the adjacent dense layer and optionally one of the layers of foamed material, is inserted into half of an open mould. Foam-forming material is then injected over the entire surface of the other mould half so that it is completely covered. Preferably, for this part of the process, a slow-foaming material producing a dense foam is used. After allowing time for specific reaction to occur, a separate machine is immediately used to pour, onto the still unhardened foam, a less dense foam-forming material. After gain allowing time for some reaction to occur, the mould is closed so that, in the final hardening reaction process, the carpet, the dense layer and the layers of foamed material having different flow resistance are joined together.

In a further process variant, a mould is used wherein the upper and lower mould halves are at different temperatures and, instead of using the chemical propellant usually employed for polyurethane foams e.g. water, there is used a physical propellant having a lower boiling point e.g. methylene chloride (boiling point 40 to 42°C). The lower mould half is then brought to a temperature below this boiling point (e.g. in the case specified to approximately 20 to 25°C) and the upper mould half is brought to a temperature above this boiling point (e.g. 45 to 50°C). In the lower mould half, the boiling point is not reached so the methylene chloride remains essentially in the liquid phase and, as a consequence of the escaping vapour having a low vapour pressure, only small pores are produced which lead to the formation of a foamed material of relatively high flow resistance. On the other hand, in the upper mould half the boiling point is exceeded so that methylene chloride passes into the vapour phase. Thus large-volume pores are produced which lead to the formation of a foamed material having low flow resistance. When the mould halves are closed, the two foams become hardened and joined together.

The noise insulation materials of the present invention can be in the form of moulded parts. However, using the process described, a sheet-form material can also be produced.

The advantage of the noise insulation materials of the present invention lies in the fact that, in spite of the limits regarding the thickness and mass of such materials which are strictly laid down by the vehicle manufacturers, their use of resilient portions comprising layers having different flow resistances enables resonance frequencies to be set up which otherwise could not be set up when using resilient portions comprising a single layer having similar physical-acoustic properties.

By means of the present invention an economical solution is offered that can be used in continuous production and which fulfills the requirement for noise insulation using relatively small installation thickness and surface mass with variably adjustable resonance frequencies.

CLAIMS

1. A noise insulation material comprising
(i) a relatively massive portion comprising a carpet and having first and second opposite surfaces, the first of said surfaces being constituted by a first surface of the carpet, and
(ii) a resilient portion comprising at least two superposed layers having different air flow resistances, the second of said surfaces of the relatively massive portion being superposed on a surface of the resilient portion.

2. A noise insulation material as claimed in claim 1 wherein said second surface of the relatively massive portion is constituted by a second opposite surface of said carpet.

3. A noise insulation material as claimed in claim 1 wherein the relatively massive portion comprises a dense layer, the carpet being superposed on a first surface of the dense layer and a second opposite surface of the dense layer constituting said second layer of the relatively massive portion.

4. A noise insulation material as claimed in claim 1, 2 or 3 wherein said layers of said resilient portion are formed on non-woven fabric.

5. A noise insulation material as claimed in claim 1, 2 or 3 wherein said layers of said resilient portion are formed of foamed material.

6. A noise insulation material as claimed in claim 5 wherein said layers of said resilient portion

are formed of cut foamed material.

7. A noise insulation material as claimed in claim 6 wherein the cut foamed material is deformed.

8. A noise insulation material as claimed in any one of the preceding claims wherein it is moulded.

9. A noise insulation material as claimed in any one of claims 1 to 7 wherein it is in sheet form.

10. A noise insulation material as claimed in any one of claims 5, 6 and 7, or either of claims 8 and 9 as appendant claim 5, 6 or 7 wherein said layers of said resilient portion comprise a layer of foamed material having a relatively low air flow resistance and a layer of foamed material having a relatively high air flow resistance located between said relatively massive portion and said layer of foamed material having a relatively low air flow resistance whereby the noise insulation material constitutes a low tuned mass-spring system having a high noise reduction.

11. A noise insulation material as claimed in any one of claims 5, 6 and 7 or either of claims 8 and 9 as appendant to claim 5, 6 or 7 wherein said layer of said resilient portion comprise a layer of foamed material having a relatively high air flow resistance and a layer of foamed material having a relatively low air flow resistance located between said relatively massive portion and said layer of foamed material having a relatively high air flow resistance whereby the noise insulation material constitutes a relatively high tuned mass-spring system with high noise reduction.

12. A noise insulation material as claimed in claim 3 or any one of claims 4 to 11 as appendant to claim 3 wherein the dense layer is a flexible dense layer.

13. A noise insulation material as claimed in claim 3 or any one of claims 4 to 11 as appendant to claim 3 wherein the dense layer is a rigid dense layer.

14. A noise insulation material as claimed in claim 3, 12 or 13 or in any one of claims 4 to 11 as appendant to claim 3 wherein the noise-reducing dense layer has a minimum surface mass of 2.0 kg/m^2.

15. A process for producing a noise insulation material as claimed in claim 5 as appendant to claim 3 which comprises providing a semi-finished product comprising said reltively massive portion, placing said portion in a close mould so that a cavity is produced adjacent said dense layer of the relatively massive portion, and introducing a foam forming material into said cavity to produce said layers of foamed material constituting said resilient portion.

16. A process according to claim 15 wherein said layers of foamed material are formed by changing the ratio of the constituents of the foam forming material during foam formation.

17. A process for producing a noise insulation material as claimed in claim 5 as appendant to claim 3 which comprises placing in an open mould, a semi-finished product comprising the carpet, the dense layer and a layer of first foamed material and then spraying, onto said layer of first foamed material, a layer of foam-forming material capable of forming layer of second foamed material having a different air flow resistance to that of the layer of first foamed material.

18. A process for producing a noise insulation material as claimed in claim 5 as appendant to claim 3 which comprises placing a semi-finished product comprising said relatively massive portion, on two layers of unhardened foamed material having different air flow resistances, and hardening the layers.

19. A process for producing a noise insulation material as claimed in claim 5 as appendant to claim 3 which comprises placing a semifinished product comprising said relatively massive portion and a layer of first foamed material on a layer of unhardened foamed material having a different air flow resistance to that of the first foamed material, and hardening said layer.

20. A process according to any one of claims 15 to 19 wherein the layers of foamed material are produced by forming a foam-forming material using a physical propellant and heating layers of the foam-forming material to different temperatures to differentially activate the propellant in the layers and thereby form layers of foamed material having different air flow resistances.

21. A process according to claim 20 wherein the foam-forming material is chemically uniform.

22. A process according to claim 20 or 21 wherein the foam forming material for the layer having a high air flow resistance is placed in a first half of a mould, the foam-forming material for the layer having a low air flow resistance is placed in a second half of the mould, the first half of the mould is heated to a temperature below the boiling point of the physical propellant, and the second half of the mould is heated to a temperature above the boiling point of the physical propellant.

23. A process according to claim 22 wherein the physical propellant is methylene chloride, the first half of the mould is heated to a temperature of 20 to 25°C, and the second half of the mould is heated to a temperature of 45 to 50°C.

24. A process for producing a noise insulation material as claimed in any one of claims 1 to 14 which comprises adhering together some or all of the layers constituting said portions.

25. A noise insulation material as claimed in claim 1 substantially as hereinbefore described.

26. A process for producing a noise insulation material as claimed in claim 1 substantially as hereinbefore described.

27. The use of noise insulation material as claimed in claims 1 to 14 or 25 in the form of a loose mat inserted in a form-fitting manner into a motor vehicle for the purpose of noise reduction in the vehicle.

28. The use of noise insulation material as claimed in claims 1 to 14 or 25 for the noise-insulation of motor vehicle passenger areas.

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